

# Market Efficiency and Government Interventions in Prewar Japanese Rice Futures Markets

Mikio Ito<sup>a</sup>, Kiyotaka Maeda<sup>b</sup> and Akihiko Noda<sup>c,d\*</sup>

<sup>a</sup> *Faculty of Economics, Keio University, 2-15-45 Mita, Minato-ku, Tokyo 108-8345, Japan*

<sup>b</sup> *Faculty of Economics, Seinan Gakuin University, 6-2-92 Nishijin, Sawara-ku Fukuoka 814-8511, Japan*

<sup>c</sup> *Faculty of Economics, Kyoto Sangyo University, Motoyama, Kamigamo, Kita-ku, Kyoto 603-8555, Japan*

<sup>d</sup> *Keio Economic Observatory, Keio University, 2-15-45 Mita, Minato-ku, Tokyo 108-8345, Japan*

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**Abstract:** This paper measures the joint degree of market efficiency in prewar Japanese rice futures markets using a non-Bayesian time-varying VAR model. We find that the two major rice futures markets (in Tokyo and Osaka) were almost efficient. We also find that government interventions involving the delivery of imported rice from Taiwan and Korea often reduced futures market efficiency. This relationship continued as long as a quality difference existed between imported and domestic rice.

**Keywords:** Futures Market; Non-Bayesian Time-Varying VAR Model; Market Efficiency.

**JEL Classification Numbers:** N25; G13; G14.

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\*Corresponding Author. E-mail: noda@cc.kyoto-su.ac.jp, Tel. +81-75-705-1510, Fax. +81-75-705-3227.

# 1 Introduction

A large body of literature has examined the efficient market hypothesis for futures markets, since Fama (1970) published his famous article. Most works in this stream of research use ordinary least squares techniques or error correction models to statistically test the parameters implicated in the hypothesis (see Cox (1976), Leuthold and Hartmann (1979), Fama and French (1987), and Chowdhury (1991)). The literature also includes some works using GARCH models to examine the volatility of futures prices (see McKenzie and Holt (2002)) and addresses not only contemporary futures markets but also historical ones. For example, economic historians have studied some examples of modern futures markets, including the Osaka-Dojima exchange, established in mid-18th-century Japan, and the Chicago Board of Trade, established in the mid-19th-century US. Both of these two famous futures markets were established for the use of traders of agricultural products, namely rice and grains. Traders in previous centuries as well as those in the 21st century generally expected that these markets would hedge the risk inherent in price fluctuations.

The principal focus of this literature has been testing the efficient market hypothesis. Through such tests, scholars have examined the performance of risk hedging in modern and contemporary futures markets for agricultural commodities, livestock, metals, oil, gas, and foreign exchange. There are far fewer works considering modern futures markets for agricultural commodities in Osaka and Chicago using data on futures prices (as noted in Perkins (1974) and Jacks (2007)).

Since much of the literature on futures focuses on whether or not the efficient market hypothesis holds for a given observation, it pays little attention to the possibility that the efficiency of the market of interest varies over time. Moreover, there are very few studies that investigate how government interventions affect market efficiency. However, governments in many countries have often intervened in markets to solve problems in the real economy, such as volatile prices caused by unstable fuel imports or price distortions and resource allocations caused by monopolistic firms. In contrast, historical governments rarely intervened in futures markets; an exception to this is the case of the rice futures market in Japan, which this paper addresses. Thus, this paper takes on two main analytic tasks. First, it examines rice futures markets in prewar Japan from the point of view that market efficiency may vary over time. Second, this paper investigates whether government intervention in the rice futures markets affected the time-varying market efficiency.

Rice futures markets in prewar Japan form a suitable case study to meet these objectives. First, Japan has a long history of a well-organized rice futures market. In particular, Schaede (1989) and Blank et al. (1991) described the Osaka-Dojima rice futures exchange in the 18th century of the Tokugawa (1603–1868) period as one of the oldest examples of a well-organized futures market. The exchange developed with official approval of the Tokugawa Shogunate, which sometimes intervened in the exchange to control rice prices (see Takatsuki (2008, ch.3)). Using data on rice futures prices during this period, some scholars have examined the efficiency of the futures market (see Ito (1993), Wakita (2001), Hamori et al. (2001), and Takatsuki (2008, ch.6)). Succeeding the Tokugawa Shogunate, the Meiji government strengthened the political function of the capital, Tokyo. Another rice futures exchange was established there by rice brokers and major merchants in 1871. This began a period in which there were two major rice exchanges, in Tokyo and Osaka. However, the Meiji government

was against the situation from the outset, as it considered dealing in rice futures to be a gamble and disruptive to the market for physical rice, a staple food of Japan. Before WWII, the Japanese government often intervened in the two major rice exchanges.

In this paper, after presenting a short history of the rice futures market in the Tokugawa, Meiji (1868–1912), Taisho (1912–1926), and prewar-Showa periods (1926–1945) of Japan, we measure the time-varying degree of market efficiency in rice futures markets using Ito et al.’s (2014) non-Bayesian time-varying vector autoregression (TV-VAR) model approach. The degree indicates the relative efficiency of the rice futures market in each period, in the weak sense of Fama (1970) when we regard the market as being highly financial. Using inference based on applying the bootstrap technique to the resulting degree estimates, we detect periods in prewar Japan in which the rice futures market was relatively inefficient. In particular, in 1890, 1898, several years after 1912, and from 1918 to 1921, less efficient markets were observed. Then, we use an event study based on the bootstrap technique of Kothari and Warner (2007) to examine whether the periods correspond to those of government interventions in the rice futures exchanges in Tokyo and Osaka. The event study confirms that every government intervention in the two major rice exchanges in the detected periods affected the rice futures price. These interventions were rooted in the government’s concern about imported rice from Korea and Taiwan, Japanese colonies at the time. Then, the government forced the exchanges to accept imported rice from Taiwan and Korea, which was of lower quality than the domestic listed rice. This resulted in reduced market efficiency in the two major rice futures exchanges, since the traders were upset by the changes in the trading rules.

The rest of this paper is organized as follows. Section 2 introduces some features of the two major rice futures markets in the Meiji, Taisho, and prewar-Showa periods and summarizes key facts of Japanese history associated with these markets. In Section 3, we present the methodology: Ito et al.’s (2014) non-Bayesian time-varying VAR model and a bootstrapping-based event study analysis. Section 4 describes the data we use, covering the two major rice futures markets in prewar Japan, and presents preliminary unit root test results. Section 5 presents the empirical results and discusses market efficiency in these exchanges. It argues that some government interventions disrupted the futures markets and reduced their efficiency. Section 6 concludes.

## 2 A History of Rice Futures Markets in Japan

In the mid-16th century, Japan was divided among various lords. In 1590, Toyotomi Hideyoshi, the strongest among them, unified the country. In the same period, Hideyoshi created the tax system and began to survey land all across Japan. His tax system, *Kokudaka-sei*, imposed heavy taxes on rice paddies. The amount of the rice tax was specified on the basis of the amount of crop grown in each paddy field. Hideyoshi’s land survey thus played the role of determining the tax amount (see Miki (1975, pp.82–85)). Under Hideyoshi’s administration, rice was used for farmers’ tax payments and for the partial payment of samurais’ salaries.

After the death of Hideyoshi, the Tokugawa Shogunate succeeded to administer Japan from the early 17th to the mid-19th century. In the Tokugawa period, rice was used as if it were money. However, rice prices showed severe volatility. Rice brokers faced the risk of

seasonal price fluctuations because rice was an agricultural product; they were eager to avoid this risk. Tokugawa Shogunate and clan governments were required to hedge against the price risk, as well, as they collected taxes and paid samurais' salaries using at least partially rice. Government actors were thus concerned about rice prices because they needed to change collected rice into money. However, there were no large rice markets in each territory where clan governments could sell large volumes of rice. Clan governments thus demanded a central market for rice in Japan, which was formed in Osaka in the middle of the 17th century.

In the 17th century, Osaka, Kyoto, and Otsu were the commercial centers of Japan. These cities, called *Kamigata*, were located along the Yodo River. Osaka in particular was characterized by having many wealthy merchants, from whom clan governments borrowed money. In the mid-17th century, Kawamura Zuiken received a contract from the Tokugawa Shogunate to transport rice and opened up the coastal sea routes. A large volume of rice was thus transported from all over Japan to Osaka because Osaka lay at the intersection of two coastal routes, along the Pacific and the Sea of Japan. Clan governments built rice warehouses or *Kura Yashiki* in Osaka; they could then change their collected rice into money and repay their loans in Osaka (see Honjo (2002, pp.244–246)).

Clan governments' warehouses often sold rice deposit warrants to traders starting in the mid-17th century. Rice traders thus began to trade not only physical rice but also these deposit warrants. However, if the rice price fell after the issuance of rice deposit warrants, clan governments faced the risk of price volatility. Under such a situation, clan governments tended to extend the shipments of rice from their warehouses. In contrast, there was no method for traders to hedge against the price risk associated with physical rice or with the rice deposit warrants. In about the early 18th century, traders began to deal in rice futures to hedge against the price volatility risk due to extending rice shipments from clan governments' warehouses. The Osaka futures market, called *Dojima Kome Kaisho* (i.e., the Dojima rice exchange), was thus authorized by the Tokugawa Shogunate in 1730 and was the world's first commodity futures exchange (Suzuki (1940, pp.17–54)). The price in the Dojima exchange was used as the index for western Japan, standardizing rice prices nationwide in the Tokugawa period (Miyamoto (1988, pp.402–403) and Takatsuki (2012, pp.315–368)).

After the Tokugawa period, the Meiji government was set up in 1868. In the Meiji period, the rice futures market in Japan developed further. The Meiji government prohibited dealing in futures at the Dojima exchange as gambling in 1869. Rice brokers in Osaka urged the government to reopen the futures market until transactions restarted in Dojima in 1871 (Tsugawa (1990, pp.26–40)). Concurrently, rice brokers in Tokyo sought to open another rice futures exchange. Hachirouemon Mitsui, a representative of rice brokers in Tokyo, began dealing in rice futures through his company, Bouekishousha, in 1871. This was followed by Chugai Shougyoukaisha, founded by wealthy merchants in Kagoshima and starting dealing in rice futures in 1874. The two companies were reorganized into Kabuto-cho Kome-Shoukaisho (i.e., the Kabuto-cho rice exchange) and Kakigara-cho Kome-Shoukaisho (i.e., the Kakigara-cho rice exchange), respectively, in 1876. Finally, the two organizations were unified in 1883 under the name Tokyo Kome-Shoukaisho (i.e., the Tokyo rice exchange) (Tokyo Grain Exchange (2003, pp.27–36)).

By the end of the 1870s, Japan's two major rice futures exchanges had thus been established in Tokyo and Osaka. Tokyo Kome-Shoukaisho (the Tokyo rice exchange) and Dojima Kome-Shoukaisho (the Dojima rice exchange) were reorganized into Tokyo Beikoku-

Torihikijo (the Tokyo rice exchange) and Osaka-Dojima Beikoku-Torihikijo (the Osaka-Dojima rice exchange), respectively, and were considered the leading markets. Rice trading volumes in the two exchanges amounted to 18.38 million *koku*, 45% of total rice futures, in 1893.<sup>1</sup> The two major exchanges continued to rank first and second in rice futures trading volumes (Ministry of Agriculture and Commerce (1900, pp.154–159)). The transaction processes at the two exchanges had much in common with their counterpart from the Tokugawa period. Standard rice was used as the basis of transactions, but market participants were allowed to transact other types of rice if agreed upon beforehand. This method of trading—i.e., trading by grade—was permitted for rice only until 1905; other types of commodities with different origins had to be singly traded. Thus, the rice futures exchanges, direct descendants of the rice futures market in the Tokugawa period, differed in nature from other futures exchanges (Maeda (2011, p.28)) and constituted a major market in prewar Japan.

In the late 1880s, rice exports from Japan were expanded. From 1885 to 1889, the amount of rice exported increased from 0.1 million *koku* to 1.3 million *koku*. This growing export volume resulted from an upturn in the terms of trade, caused by stable silver prices, and a decrease in the price of domestic rice at the time (Omameuda (1993, pp.18–20)). However, population increases amid high growth rates in major cities such as Tokyo and Osaka caused growing consumption of rice after Japan experienced a serious rice harvest failure in 1890. Rice exports thus showed a rapid decrease.

Since the 1890s, Japan had been a continuous importer of rice. In the 1890s, Japan imported rice from countries in Southeast Asia, but starting in the 1900s, the amount of rice imported from Japanese colonies increased.<sup>2</sup> These colonies were the supply centers of rice to the Japanese home islands. In fact, Taiwan and Korea supplied a large portion of imported rice in Japan; colonial rice amounted to 48% of total imported rice in the 1910s (see Ministry of Agriculture and Forestry, Department of Agriculture (1932, pp.4–5)). The Ministry of Agriculture and Commerce, which held jurisdiction over the administration of commodity exchanges, often ordered the exchanges to change the transaction rules regarding the delivery of imported rice to adjust to the increasing volumes of rice imports starting in the 1890s. Table 1 reports the periods in which the ministry issued such orders and the contents of each of the orders.

(Table 1 around here)

According to Table 1, we find that after 1912 the Ministry of Agriculture and Commerce forced the exchanges to consider the delivery of imported rice from Taiwan and Korea on a steady basis. The Japanese government amended the transaction rule in order to control rice prices. However, the rice exchanges opposed these amendments. For example, in 1912 when the Ministry of Agriculture and Commerce forced the rice exchanges to steadily accept imported rice from Taiwan and Korea as an alternative to the listed domestic rice, rice exchanges all over Japan released a statement denying any amendment to the transaction rule. The exchanges said in a statement:

The rice futures price will fail to be an acceptable index of the expected spot

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<sup>1</sup>*Koku* is a unit of rice trading volume. One *koku* is equal to 180.39 liters.

<sup>2</sup>Japan colonized Taiwan in 1895 and Korea in 1910.

price of rice because Taiwanese and Korean rice is different from domestic rice in quality.<sup>3</sup>

Indeed, Taiwanese and Korean rice was indica variety whereas domestic rice was japonica variety. In addition, traders had other complaints about rice from Taiwan and Korea. Taiwanese rice varied considerably in quality because rice farming in Taiwan used double cropping (see Ministry of Agriculture and Forestry, Rice Bureau (1938, p.27)). Meanwhile, Korean rice was often intermixed with sand, stones, and other trash (see Hishimoto (1938, p.598)). Korean rice was concentrated in Osaka because only Osaka’s rice traders could decontaminate Korean rice (see Ministry of Agriculture and Forestry, Rice Bureau (1938, p.20)). In short, rice traders did not regard Taiwanese and Korean rice as being of the same quality as domestic rice.

In practice, although the Ministry of Agriculture and Commerce expected the amendment of the transaction rule to rein in rice prices, the futures price of rice did not fall in 1912. The Ministry of Agriculture and Commerce was puzzled by this situation (see Tokyo Asahi Shimbun (1912)). In 1918, it forced the exchanges to accept the delivery of low-quality domestic rice and change the standard rice from medium quality to low quality. The purpose of this change was also to control the rice price. In sum, despite these ordered changes to transaction rules, the government was unable to control rice futures prices, and the exchanges recognized that the government intervention had caused a dislocation in the rice market.

In 1918, Japan experienced nationwide riots, kome-soudou (“the Rice Riots”), which caused the Terauchi cabinet to resign and left Japan in disorder. New legislation was then required to manage this rice price inflation. Beikoku-hou (the Rice Law), passed in 1921, enabled the government to directly intervene in markets to adjust prices. The policy was intensified in 1925 and 1931 through revisions to the law and further modified by the Beikoku-tousei-hou (Rice Supply and Demand Regulation Law), issued in 1933. The rice futures markets, which were supposed to be free, were thus increasingly controlled by the government starting in 1921.

### 3 The Methods

In this section, we present our empirical method for examining the market integration and efficiency of rice futures markets in the Meiji, Taisho, and prewar-Showa periods in Japan (1868–1945). We consider these entities as established financial markets. Our method consists of two approaches: a non-Bayesian time-varying model approach as in Ito et al. (2014) and a event study based on a bootstrap technique by Kothari and Warner (2007). The first approach aims at examining market efficiency in the two rice futures markets, which were almost 250 miles (400 kilometers) apart and might vary their market efficiency; the second one aims at investigating the impact of government interventions in the markets on their rice futures prices.

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<sup>3</sup>See Ministry of Agriculture and Forestry (1959, p.107).

### 3.1 A Non-Bayesian Time-Varying Model Approach

Fama (1970) asserts that the financial commodity price in an efficient market instantly reflects any instantaneous shock. In other words, there is no persistent propagation of such a shock on the rate of return in an efficient market. Based on this contention, our analytical approach begins with impulse response analysis of rates of return in time series data. Since the impulse response reflects the propagation of an instant shock to the system, the aggregation of the impulse responses represents the full effects of the shock.

It is standard to employ a VAR model with finite lags when attempting to obtain impulse responses for multivariate data:

$$\mathbf{y}_t = \boldsymbol{\nu} + A_1 \mathbf{y}_{t-1} + \cdots + A_p \mathbf{y}_{t-p} + \mathbf{u}_t; \quad t = 1, 2, \dots, T, \quad (1)$$

where  $\mathbf{y}_t$  is a vector of rates of return for rice futures in the Tokyo and Osaka exchanges.

From equation (1), a VMA( $\infty$ ) model representing the impulse responses is obtained through a series of calculations. Note that we regard the VAR( $p$ ) model as a reduced form of the VMA( $\infty$ ).

$$\mathbf{y}_t = \boldsymbol{\mu} + \Phi_0 \mathbf{u}_t + \Phi_1 \mathbf{u}_{t-1} + \Phi_2 \mathbf{u}_{t-2} + \cdots; \quad t = 1, 2, \dots, T, \quad (2)$$

As mentioned above, we will calculate  $\sum_{\tau=0}^{\infty} \Phi_t$  given VMA( $\infty$ ) and then derive a norm from the matrix as a measure of the degree of persistent effects of the instantaneous shock. Following Ito et al. (2014), we adopt the spectral norm of the difference between  $\sum_{\tau=0}^{\infty} \Phi_t$  and an identity matrix  $I$ ,  $\sum_{\tau=0}^{\infty} \Phi_t - I$ . Since  $\Phi_0$  is identical to  $I$ , it reflects all effects except those of the shock.

Our approach is secondly drawn from the time-varying estimation technique of Ito et al. (2014). This technique allows us to obtain impulse responses at each period supposing a VAR( $p$ ) model. Then we can derive impulse responses,  $\{\Phi_{0,t}, \Phi_{1,t}, \Phi_{2,t}, \dots\}_{t=1, \dots, T}$ , depending on time  $t$ .

$$\mathbf{y}_t = \boldsymbol{\mu}_t + \Phi_{0,t} \mathbf{u}_t + \Phi_{1,t} \mathbf{u}_{t-1} + \Phi_{2,t} \mathbf{u}_{t-2} + \cdots \quad (3)$$

Finally, we compute each degree of market efficiency  $\zeta_t$  at  $t = 1, \dots, T$  as follows.

$$\zeta_t = \sqrt{\max \lambda \left[ \left( \sum_{\tau=0}^{\infty} \Phi_t - I \right)' \left( \sum_{\tau=0}^{\infty} \Phi_t - I \right) \right]}, \quad (4)$$

where “ $\max \lambda[X]$ ” denotes the maximum eigenvalue of a matrix  $X$ . The sequence of  $\zeta_t$ , ( $t = 1, \dots, T$ ) provides information about the time-varying nature of the rice futures markets’ efficiency. Since the above method is based on a linear time series model, a usual residual bootstrap technique can be used to facilitate statistical inference regarding the time-varying impulse responses and the degree of market efficiency.

### 3.2 Bootstrap Inference for Event Study Analysis

Recently, event studies have been increasingly used in economic history research (see Willard et al. (1996), and Bittner (2005) for examples). An event study measures and assesses the impact of a specific event on a financial outcome, such as the value of a firm. In fact, event studies have often been used in economics and finance to measure impacts of a shock on the returns to securities. Most such applications focus on the effect of an event on the price of a particular class of the firm's securities. This paper, in contrast, adopts this method to examine the relationship between the results of time-varying market efficiency and actual government interventions. In particular, we use it to confirm whether the government interventions had impacts on the returns to rice futures prices.

When beginning an event study, it is essential to define the event of interest and specify the period in which the security prices are expected to depend on the event. This period is called the event window. Then, it is necessary to choose selection criteria for the study. When considering the event's impact, one must pay close attention to abnormal returns (ARs).

$$AR_{it} = R_{it} - E[R_{it} | \mathcal{I}_{it}]$$

where,  $AR_{it}$ ,  $R_{it}$ , and  $E[R_{it} | \mathcal{I}_{it}]$  are the abnormal, actual, and normal returns, respectively. The subscript  $i$  denotes each issue; it presents the two rice futures in the Tokyo and Osaka exchanges. With monthly futures data, a simple model is applied to measure the normal return as the mean level of returns in the periods preceding the event window. Here, the return in each period is indexed by  $t$ . We define  $t = 0$  as the event date and let  $\tau = T_1 + 1$  to  $\tau = T_2$  represent the event window and  $\tau \leq T_1$  the estimation window. Note that  $T_1 + 1 \geq 0 \geq T_2$  since the event window should contain the event date  $t = 0$ .

When we conduct an event study, the cumulative abnormal return (CAR) within the event window, rather than the specific abnormal returns, is usually used. Specifically, the CAR is defined using the ARs as follows:

$$CAR_{it} = \sum_{\tau=T_1}^t AR_{i\tau}, (\tau_1 \geq t \geq \tau_2)$$

for some  $\tau_1 > T_1$  and  $\tau_2 < T_2$ . We assess the impact of the event, as captured in our data, based on the distribution of CARs within the event window, especially at the event date  $t = 0$ . The distribution has conventionally been derived by summing the normal distributions, which previous event studies have usually assumed to apply. In contrast, we adopt a bootstrap technique to infer the distribution, as bootstrapping provides robust inference without relying on parametric assumptions (see Kothari and Warner (2007) on the advantages of bootstrap inference in event studies).

The bootstrap inference procedures for event studies are as follows. First, suppose there are  $N$  events.<sup>4</sup> Let each event correspond to a time series of CARs in event time, within the event window. The overall summary statistic of interest is the  $\overline{CAR}$ , the average of

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<sup>4</sup>In this paper, we are interested in each government intervention in the two rice exchanges (Tokyo and Osaka) at the same time. Thus, one should regard  $N$  as 2.



all the CAR time series. Second, each bootstrap sample is constructed by sampling with replacement,  $N$  times, within the dataset of  $N$  events. For each event, the corresponding CAR time series is obtained. This yields a time series of CARs, which is one draw from the distribution of the statistic. Third, this procedure is repeated 1000 times to obtain the bootstrap distribution of CARs. Finally, percentiles of the distribution are calculated and graphs are drawn to show bootstrap confidence intervals for our estimates. In particular, we pay attention to the interval for  $t = 0$ . If it does not contain zero, we regard the event as the impact on the returns to rice futures.

## 4 Data

For this analysis, we use a dataset of monthly Tokyo and Osaka rice futures prices during and after the Meiji period (from January 1881 through November 1932). This is an old continuous monthly dataset for a well-established futures market.

For rice futures prices in Tokyo and Osaka, we utilize monthly mean values for the deferred contract (three months). The dataset is mostly that used in Nakazawa (1933), obtained mainly from the *Annual Statistical Report of the Tokyo Chamber Commerce* (Tokyo) and *Osaka City Statistics* (Osaka). There were a few missing values in the statistics created by Nakazawa (1933), some of which are sequential, with the longest missing sequences being three months. These missing values are filled in using a seasonal Kalman filter, and we take the first difference of the natural log of rice futures prices to compute the ex-post return series.

In the estimations, all variables appearing in the regression equations are assumed to be stationary. To check whether the variables satisfy the stationarity condition, we apply the ADF-GLS test of Elliott et al. (1996). Together with the procedure proposed by Ng and Perron (2001), this unit root test is robust to size distortions. Table 2 shows the results of the unit root test along with descriptive statistics for the data. The ADF-GLS test rejects the null hypothesis that the variable contains a unit root at the 1% significance level.<sup>5</sup>

(Table 2 around here)

## 5 Empirical Results

### 5.1 Measuring the Time-Varying Degree of Market Efficiency

Following the methods described in Section 3.1, we first verify that the TV-VAR model is more appropriate than the traditional, time-invariant VAR model. In particular, we estimate the time-invariant VAR model with the whole sample and then apply Hansen's (1992) parameter constancy test to investigate whether the time-invariant model is a better fit for our data.

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<sup>5</sup>For selecting the optimal lag length, we employ the modified Bayesian information criterion (MBIC) instead of the modified Akaike information criterion (MAIC) because we are unable to identify size distortions in the estimated coefficient of the detrended series,  $\hat{\psi}$  (Elliott et al. (1996) and Ng and Perron (2001)).

(Table 3 around here)

In order to select the lag lengths, we adopt the BIC (Schwarz (1978)). Table 3 presents the time-invariant VAR estimates and Hansen’s (1992) joint parameter constancy test statistics (in the last row, “ $L_C$ ”). For our time-invariant VAR model, the parameter constancy test rejects the null hypothesis of constancy at the 1% significance level against the alternative hypothesis that the parameter variation follows a random-walk process. These results suggest that the time-invariant VAR model does not apply to our data and that the TV-VAR model is a better fit.

Our measure of market efficiency captures how much the observed market deviates from an efficient one. Thus, we can clarify how the underlying market evolves by examining the degree of change over time. As mentioned in Section 3, we focus on the TV-VAR model and the amount of market efficiency associated with this model. Once again, the deviation from efficient conditions in these futures markets is measured by (4), the spectral norm. If  $\zeta_t = 0$  for time  $t$ , the two futures markets are jointly efficient.

We compute the degree of market efficiency from the estimates of  $\Phi_t(1)$ ; therefore,  $\zeta_t$  is subject to sampling error. We thus include a confidence band for  $\zeta_t$  under the null hypothesis of market efficiency. We find no evidence of inefficient markets whenever the estimated  $\zeta_t$  is less than the upper limit of the confidence band; inefficient markets are detected with an estimated  $\zeta_t$  that is larger than the upper limit. Following Ito et al. (2014), we adopt a residual-based bootstrapping technique for our TV-VAR model to construct the confidence interval. This consists of three steps: (i) we generate multivariate i.i.d. processes for futures returns,  $y_t$ ; (ii) we apply and estimate the TV-VAR model for those processes; and finally, (iii) we compute  $\zeta_t$ .

(Figure 1 around here)

Figure 1 shows that the examined rice futures markets are generally efficient. However, it also shows that the degree of market efficiency varies over time: it is relatively lower starting in the late 1910s, and the markets were inefficient around 1890 and in the early 1920s. These changes in market efficiency stem from government interventions in the exchanges’ transaction rules for rice futures.

## 5.2 Event Studies

This subsection presents empirical evidence, drawn from the event study, of the impact of government interventions in the rice futures exchanges on prices before examining the time-varying efficiency of the markets.

Table 1 summarizes chronological government interventions in the two major rice futures exchanges in Tokyo and Osaka within the period covered by our data. Before discussing our event study, we will further explain the contents of this table. First, it shows that imported rice was temporarily deliverable in the exchanges from May to November 1890, from January to October 1898, and from June to October 1912. Table 1 also shows that imported rice became deliverable on a steady basis as a result of government intervention in March 1913. However, on 28 November 1912, the Ministry of Agriculture and Commerce issued a notice to the exchanges about an amendment to the transaction rule in March 1913

(see Ministry of Agriculture and Forestry (1959, p.107))<sup>6</sup>. Therefore, in reality, the ministry consistently forced the rice exchanges to accept imported rice as an alternative to listed domestic rice on a steady basis starting in June 1912. Although the ministry abolished the order on delivery for rice from Taiwan in July 1914, the exchanges had been accepting the delivery of imported rice from Korea since March 1913. In short, imported rice was deliverable in the exchanges from May to November 1890, from January to October 1898, and after June 1912.

In addition, Table 1 reveals two points regarding amendments to rules governing the exchanges' trade in domestic rice. First, low-quality domestic rice was deliverable in the exchanges from April 1918 to December 1920 and after November 1921. Second, the Ministry of Agriculture and Commerce forced the exchanges to change the quality of standard rice to low in April 1918 and November 1919. However, the cause of the variation in market efficiency from the late 1910s until the early 1920s is not evident, as the Ministry of Agriculture and Commerce intervened in the rice futures exchanges at very short intervals. In this section, we will focus the interventions in November 1919. According to Table 1, the exchanges had the widest variety of rice deliverable and accepted the lowest quality of standard rice from November to December 1919.

We summarize the results of our event study into the impact of government interventions in the rice futures exchanges in Figure 2. The four panels of the figure present the results for the examinations of the government interventions in May 1890, January 1898, June 1912, and November 1919, respectively. These events are expected to have stronger impacts on the futures markets from the futures traders' point of view, as pointed out above. The horizontal axis of each panel represents the time periods within the event window, of which the center, 0, indicates the event time, as explained in Section 3.2. The vertical axis for each panel presents the CAR to the event. The solid line in each panel indicates the value of the CAR at different points within the event window. The upper and lower dashed lines indicate 97.5% and 2.5% quantiles, respectively, of the bootstrap-based distributions for the different periods. All panels for May 1890, January 1898, June 1912, and November 1919 suggest that the impacts of the four government interventions affected the rice futures markets with 95% confidence. In fact, no bands built using the two dashed lines contain the origin (0,0). In particular, the 95% band built using bootstrapping for November 1919 clearly deviates from zero (see the bottom left panel of Figure 2).

### 5.3 *Historical Interpretation*

#### 5.3.1 The Amendment of Transaction Rule in 1890

In 1890, an amendment to the transaction rule forced the exchanges to accept the delivery of imported rice for the first time (see Table 1). This disrupted the efficiency of transactions in the futures markets of Tokyo and Osaka, and their traders showed strong opposition. In May 1890, the Tokyo rice wholesalers association issued a statement of strong disagreement with the amendment to the transaction rule, as follows.

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<sup>6</sup>In the cases in 1890 and 1898, the Ministry of Agriculture and Commerce notified the exchanges about a temporary amendment to the transaction rule on 17 April 1890 and 11 December 1897 (see Ministry of Finance, Financial Bureau (1919, pp.191–194) and Ministry of Agriculture and Forestry (1959, p.97))

“The imported rice is different from the domestic rice in quality and use. If the exchanges accept the delivery of imported rice, movements of futures prices will not be similar to those in the spot prices of domestic rice. Therefore, the futures price will fail to be a fine index of the expected price of rice. We expect that the rice exchange will become instead a gambling place.”<sup>7</sup>

Because the imported rice was different in quality from domestic rice, as mentioned in Section 2, the uses were also not the same. In 1890, imported rice was used as the raw material for *sake* (liquor), *shochu* (spirits), and vinegar, while domestic rice was used for food (see Tokyo Keizai Zasshi (1890a)). That is, Japanese consumers did not regard imported and domestic rice as being the same. The distribution of imported rice within Japan differed between regions, with more found in Osaka than in Tokyo. From October 1889 to June 1890, the volume of rice imported into the ports of Osaka and nearby Kobe was 482 thousand *koku* in total, while that for Yokohama, near Tokyo, was 247 thousand *koku*. The volume of rice imported into Osaka and Kobe was about 68% of the total volume of rice imported in the same period (see Tokyo Keizai Zasshi (1890c)). Therefore, the increase in rice imports had a greater impact on the rice market of Osaka than on that of Tokyo. The Osaka-Dojima rice exchange opposed changes to trading rules that allowed imported rice to be deliverable as an alternative listed good. The Ministry of Agriculture and Commerce revoked the exchange’s permission to deal in reaction to its disobedience (see Tokyo Keizai Zasshi (1890d)). Dealing in the Osaka-Dojima rice exchange stopped temporarily, and this series of serious disruptions reduced market efficiency still further. In fact, the Ministry of Finance reported that the amendment to the transaction rule suppressed futures prices, although the spot price did not change (see Ministry of Finance, Financial Bureau (1919, p.194)). That is, the futures price failed to be a fine index of the expected price of rice, as the Tokyo rice wholesalers association had predicted. When imported rice was temporarily made deliverable for a second time in 1898, the intervention caused a smaller disruption to the exchanges than it had in 1890. Thus, while the exchanges experienced low market efficiency, our analysis noted no significant change in the degree of market efficiency.

### 5.3.2 The Amendment of Transaction Rule in 1898

In 1898, the rice price soared because Japan took a hit from a poor rice harvest in the previous year. In January 1898, the Ministry of Agriculture and Commerce ordered the exchanges to change the transaction rule regarding the delivery of imported rice as a way of suppressing the price increases. However, this amendment of the transaction rule had poor efficacy in terms of price control due to a record harvest of rice and barley in 1898. In prewar Japan, barley was widely used as a substitute for rice and thus also impacted the rice price. The two crops had different seasons: rice was grown in the fall, while the harvest season for barley was in early summer. In May 1898, newspapers reported that the barley harvest would be a good one (see Tokyo Asahi Shimbun (1898)). In July 1898, the forecast for a good rice harvest was reported by the newspapers (see Yomiuri Shimbun (1898b)); indeed, the Ministry of Agriculture and Commerce reported the resulting harvest as a record crop since record-keeping began (See Ministry of Agriculture and Commerce (1900, p.1)).

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<sup>7</sup>See Tokyo Keizai Zasshi (1890b, p.577)).

The total volume of rice produced in 1898 was 4.7 million *koku*, 43% greater than in the previous year (see Ministry of Agriculture and Commerce (1900, pp.1–2)). Under this supply situation, rice traders began to perceive rice imports as excess starting in May 1898, when the volume of imported rice inventory increased in the warehouses at the port of Yokohama (see Yomiuri Shimbun (1898a)). Put simply, consumers avoided buying imported rice because the newspapers forecast good harvests for rice and barley. Moreover, futures transactions were also disrupted, with some observing that the exchanges failed to offer a fine index of the expected price of rice. In August 1898, Yomiuri Shimbun reported this situation as follows.

“After January, when the delivery of imported rice in the rice exchanges began, the rice futures market was dependent on price fluctuations for imported rice. As a result, the trend in rice futures prices was different from that in the spot price.”<sup>8</sup>

On the other hand, rice traders, as represented by the Tokyo rice wholesalers association, did not issue a statement of strong disagreement with the transaction rule amendment, as was the case in 1890. Because imported rice was not actively being transacted, government intervention caused a smaller disruption in the exchanges in 1898 than it had in 1890.

### 5.3.3 Frequent Government Interventions in the 1910s

The Ministry of Agriculture and Commerce very often ordered the exchanges to change transaction rules related to the delivery of Taiwanese and Korean rice starting in 1912. In 1913 this imported rice began to be deliverable on a steady basis; the amendment related to rice from Taiwan was abolished, while that for rice from Korea was retained. In addition, lower quality domestic rice became deliverable after the Ministry of Agriculture and Commerce extended the variety of rice deliverable in the rice futures exchanges in 1918 and 1919. Imported rice from Taiwan became deliverable again in 1919 as part of a government intervention to suppress rice prices (see Table 1). This series of government interventions in rice futures exchanges reduced their market efficiency.

The rice traders opposed this series of government interventions, as mentioned in Section 2. In addition, some government officials admitted the failure of their interventions in rice futures market. In 1918, Kawai Yoshinari, Director of the Division of Foreign Rice Management at the Ministry of Agriculture and Commerce and responsible for controlling the rice market to stabilize prices and transactions, said that the rice futures market was faced with deterioration, as follows.

“Essentially, the price difference between the spot and the futures prices vanishes at the maturity date. However, after the exchanges began to regard the delivery of imported rice, the price difference between the spot and futures prices did not fall with the maturity date. The futures market showed hardly any relationship with the spot market because the rice futures market was strongly dependent on the price of rice from Taiwan and Korea. The function of the exchange is thus disrupted.”<sup>9</sup>

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<sup>8</sup>See Yomiuri Shimbun (1898c).

<sup>9</sup>See Kawai (1921, pp.300–301).

Regarding the policy summarized above, he thus conceded that it was not functional. In addition, between 1918 and 1921 the Ministry of Agriculture and Commerce often forced the exchanges to extend the variety of rice deliverable and to change the standard rice in the rice futures exchanges; as a result, the market efficiency fell markedly. In fact, the Tokyo Asahi Shimbun reported that these changes to the transaction rules greatly enlarged the price difference between the spot and the futures prices after 1918 (see Tokyo Asahi Shimbun (1920)). That is, the reduction in market efficiency occurred in the 1910s and early 1920s because the Ministry of Agriculture and Commerce forced the exchanges to amend the transaction rules frequently. This was especially true from 1918 to 1921, when the Ministry of Agriculture and Commerce intervened in the rice futures exchanges at very short intervals.

The Rice Law, based on the lessons and reflections from *kome-soudou* (the Rice Riots) in 1918, was established in 1921. The Rice Law permitted the government to buy and sell physical rice directly to adjust the supply-demand balance as well as rice prices. When the Great Kanto Earthquake occurred in Tokyo in September 1923, the Japanese government announced the purchase of 1.35 million *koku*, 2.4% of the 1922 domestic production of 55.18 million *koku*, to be sold to earthquake victims. While the amount actually purchased was 0.59 million *koku*, the government strongly affected prices in the rice exchanges by announcing the direct purchase of such a large volume (see Ministry of Agriculture and Forestry (1959, p.164)).

One hundred thousand people in Tokyo and surrounding areas died in the Great Kanto Earthquake in 1923. In addition to this massive human suffering, the Tokyo rice exchange building was completely destroyed, and rice futures dealings stopped for two months. Also destroyed in a fire was 75% of the government's rice, 267 thousand *koku*, which had been stored in the area surrounding Tokyo. The government thus transported 456 thousand *koku* of rice from western Japan to help the victims and sold it at the official price in Tokyo, Yokohama, and Yokosuka. Because of these disruptions to the rice market, market efficiency in the rice exchanges fell markedly. However, after the exchanges restarted in November 1923, their market efficiency again improved despite the delivery of Korean rice in the exchanges (see Table 1), resulting from differences in quality between domestic and Korean rice.

#### 5.3.4 The 1920s Policy for Uniform Rice Quality

The Governor-General of Korea promoted japonica rice cultivation in the colony beginning in the 1910s. From only 5% of total rice production in 1912, japonica production jumped to 69% in 1921 and 79% in 1932 (see Tohata and Okawa (1939, pp.438–439)). This policy resulted in shrinking the difference between rice prices in Korea and those in inland Japan starting in the 1920s, as Japanese consumers began to regard rice imported from Korea as being of the same quality as domestic rice (see Onameuda (1993, p.195)). As a result, even when rice imported from Korea was delivered for futures transactions, market participants were no longer worried about the risk of delivery of low-quality rice. In fact, the exchanges recognized that the quality of Korean rice had improved. From January 1927, all rice exchanges in Japan raised their grade of Korean rice (see Tokyo Asahi Shimbun (1926)). After the Great Kanto Earthquake, market efficiency in the two major rice futures markets

improved.<sup>10</sup>

## 6 Conclusion

This paper has measured the time-varying joint degree of market efficiency of the two major rice futures markets in prewar Japan and investigated the factors that altered market efficiency. It has argued that the two major rice futures markets were nearly efficient, although there were several periods during which government interventions concerning trading rules reduced their market efficiency.

Starting in 1890, the government forced the rice exchanges to accept deliverable imported rice from Taiwan and Korea as an alternative to the domestic listed rice. However, before the early 1920s, the rice imported from Japanese colonies was of notably different quality than domestic rice. Thus, most rice traders did not regard this rice as being of the same quality as standard domestic rice. Ignoring the context of rice futures dealings, the government forced the exchanges to regard the imported rice from Taiwan and Korea as deliverable rice in the futures exchanges, resulting in reduced efficiency in rice futures dealings for several periods.

When the rice price rose quickly in the late 1910s, the government extended the range of deliverable rice in the rice futures exchanges to reduce the price of physical rice. Since the newspapers reported that the intervention expanded the gap between spot and future prices, the market efficiency of rice futures dealing fell. Frequent government intervention in the markets thus reduced the efficiency of rice futures during the 1910s. The rice futures markets improved their efficiency starting in the mid-1920s due to the decrease in the quality difference between domestic rice and that imported from Korea after the Governor-General of Korea promoted domestic rice cultivation.

## Acknowledgments

We would like to thank Shigehiko Ioku, Junsoo Lee, Minoru Omameuda, Kentaro Saito, Rainer Schüssler, Masato Shizume, Yasuo Takatsuki, Tatsuma Wada, Wako Watanabe, and Asobu Yanagisawa for their helpful comments and suggestions. We would also like to thank seminar and conference participants at Wakayama University; the Japanese Economics Association 2014 Spring Meeting; and the 89th Annual Conference of the Western Economic Association International for helpful discussions. We also thank the Japan Society for the Promotion of Science for their financial assistance, as provided through the Grant in Aid for Scientific Research Nos. 26380397 (Mikio Ito), 26780199 (Kiyotaka Maeda), and 15K03542 (Akihiko Noda). All data and analysis code used for this paper are available on request.

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<sup>10</sup>Note that market efficiency was relatively low during the post-disaster reconstruction period because the government intermittently bought and sold rice under the Rice Law.

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Table 1: Government Interventions in the Rice Futures Exchanges

Date	Orders and Amendments
May, 1890	Rice futures exchanges accept imported rice as an alternative to listed domestic rice.
November, 1890	The amendment of May 1890 is abolished.
January, 1898	The amendment of May 1890 is revived.
October, 1898	The amendment of January 1898 is abolished.
June, 1912	Rice futures exchanges accept imported rice from Taiwan and Korea as an alternative to listed domestic rice.
October, 1912	The amendment of June 1912 is abolished.
March, 1913	The exchanges accept imported rice from Taiwan and Korea as an alternative to listed domestic rice on a steady basis.
August, 1914	Rice from Taiwan is undeliverable.
April, 1918	Low-quality domestic rice is deliverable and the exchanges accept a change to the standard rice from medium quality to low quality.
February, 1919	Rice from overseas is deliverable.
November, 1919	Lowest quality domestic rice is deliverable and the exchanges accept a change to standard rice from low quality to lowest quality.
December, 1919	Rice from overseas (excluding Korea) is undeliverable.
October, 1920	The exchanges accept a change to standard rice from lowest quality to medium quality.
December, 1920	Lowest and low-quality domestic rice is undeliverable.
November, 1921	Low-quality domestic rice is deliverable.

Sources:

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Table 2: Descriptive Statistics and Unit Root Tests

	Mean	SD	Max	Min	ADF-GLS	Lags	$\phi$	$\mathcal{N}$
Tokyo	0.0012	0.0626	-0.3189	0.3860	-20.4604	0	0.1930	622
Osaka	0.0013	0.0633	-0.3069	0.2523	-20.6532	0	0.1841	622

Notes:

- (1) “ADF-GLS” denotes the ADF-GLS test statistics, “Lags” denotes the lag order selected by the MBIC, and “ $\hat{\phi}$ ” denotes the coefficients vector in the GLS detrended series (see Equation (6) in Ng and Perron (2001)).
- (2) In computing the ADF-GLS test, a model with a time trend and a constant is assumed. The critical value at the 1% significance level for the ADF-GLS test is “−3.42.”
- (3) “ $\mathcal{N}$ ” denotes the number of observations.
- (4) R version 3.2.1 was used to compute the statistics.

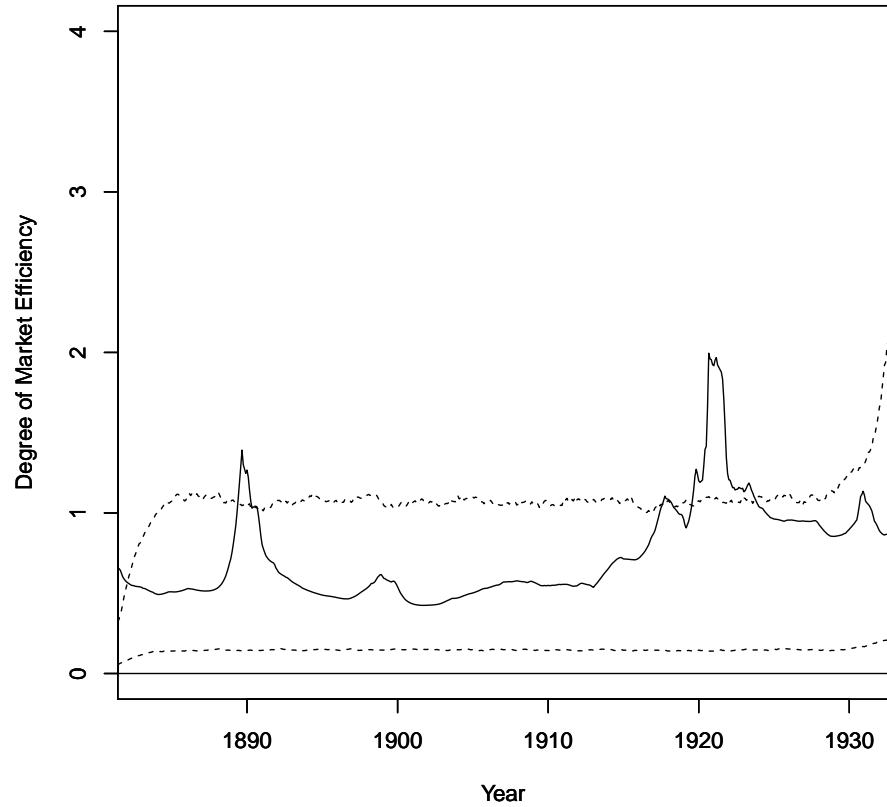
Table 3: Time-Invariant VAR Estimations

	Tokyo	Osaka
Constant	0.0014 [0.0024]	0.0010 [0.0018]
$R_{t-1}^{tokyo}$	0.0629 [0.0720]	0.1170 [0.0362]
$R_{t-1}^{osaka}$	0.1561 [0.0701]	0.0385 [0.0553]
$R_{t-2}^{tokyo}$	-0.0268 [0.0421]	0.5453 [0.0792]
$R_{t-2}^{osaka}$	-0.0263 [0.0585]	-0.4130 [0.0517]
$R_{t-3}^{tokyo}$	-0.1750 [0.0599]	0.0495 [0.0496]
$R_{t-3}^{osaka}$	0.0122 [0.0472]	-0.0916 [0.0394]
$R_{t-4}^{tokyo}$	0.0300 [0.0544]	0.2329 [0.0606]
$R_{t-4}^{osaka}$	-0.0174 [0.0399]	-0.0871 [0.0393]
$\bar{R}^2$	0.0336	0.2644
$L_C$	68.7284	

Notes:

- (1) “ $\bar{R}^2$ ” denotes the adjusted  $R^2$ , and “ $L_C$ ” denotes Hansen’s (1992) joint  $L$  statistic with variance.
- (2) Newey and West’s (1987) robust standard errors are in brackets.
- (3) R version 3.2.1 was used to compute the estimates and the test statistics.

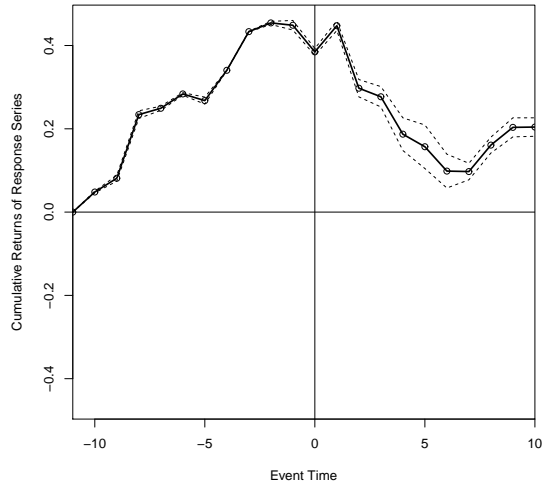
Figure 1: The Time-Varying Degree of Market Efficiency



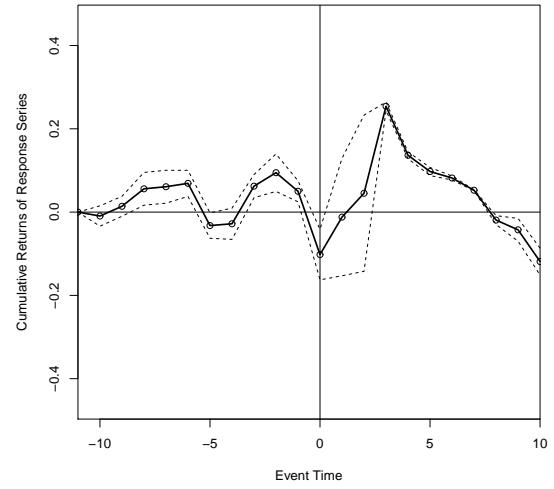
Notes:

- (1) The dashed lines represent the 95% confidence bands of the time-varying spectral norm in the case of an efficient market.
- (2) We ran bootstrap sampling 5000 times to calculate the confidence bands.
- (3) R version 3.2.1 was used to compute the estimates.

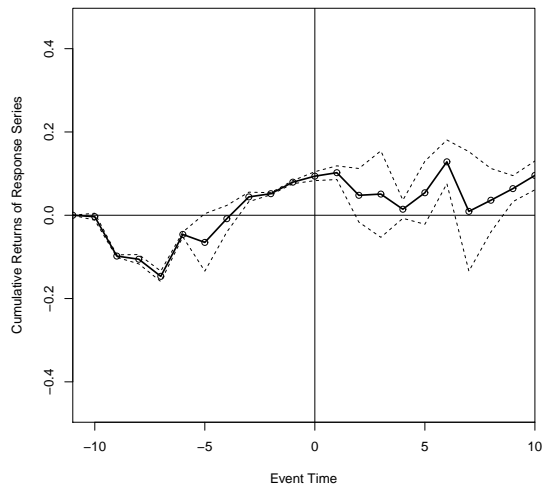
Figure 2: Event Study Analysis



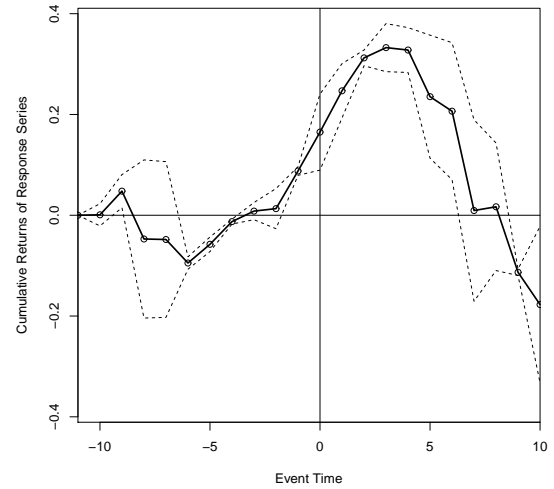
(a) May 1890



(b) January 1898



(c) June 1912



(d) November 1919

Notes:

- (1) The dashed lines represent the 95% bootstrap confidence bands for the event study analysis.
- (2) R version 3.2.1 was used to compute the estimates.